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NONMETALLIC MINERALS NEEDED FOR NATIONAL DEFENSE:

2. ABRASIVES

BY

LEO J. O'NEILL

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

NONMETALLIC MINERALS NEEDED FOR NATIONAL DEFENSE:

2 - ABRASIVES 1/

By Leo J. O'Neill 2/

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INTRODUCTION

Abrasives are essential to the manufacture of munitions - airplanes, guns, shells, tanks, and in fact every product that involves metal forming or finishing. An indication of the importance of abrasives in the national defense and aid-to-Britain programs is the close peace-time correlation between demand for abrasives and automobile production, which in recent years has consumed more than 35 percent of the total output of abrasives.

Unprecedented demands on the abrasives industry are forecast by the rapid expansion in airplane output, the increased mechanization of all armed forces, and the consequent speeding up not only of the factories where finished munitions are made but also of the steel mills and other factories where additional large quantities of abrasives are needed for snagging or rough-grinding semifinished products before they can be used by the fabricators. A recent survey by the artificial abrasives manufacturers indicates that they can readily increase their output 75 percent compared with the previous peak of 1937 without building new plants. By overhauling production schedules, their maximum production possible could be increased to 182 percent of the 1937 output, and the nature of the industry is such that plant capacity could be increased rapidly if need therefor should arise. No figures on the estimated requirements for abrasives in 1941 or 1942 have as yet been compiled, but the industry feels that it can meet demands as they develop.

1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7168."

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Even with a complete stoppage of sea-borne traffic, the United States could attain self-sufficiency in regard to all necessary abrasives except industrial diamonds.

GENERAL TRENDS

Table 1 shows imports for consumption of abrasives and abrasive materials for 1919, 1929, and 1937. In table 2 domestic production statistics for the same years are shown. Figures for 1937 represent peak production for silicon carbide, fused alumina, and certain other items. It is significant that the Federal Reserve Board index (revised) of general industrial production in that year likewise exceeded the previous high record established in 1929.

Table 3 shows the growth in the United States of the principal manufactured abrasive products from 1880 to 1939. In this table the figures from 1931 to 1939 only are strictly comparable. They represent establishments engaged primarily in the manufacture of abrasive grinding wheels of emery, corundum, and other materials; abrasive sticks, stones, and bricks made from purchased materials; abrasive paper and cloth; and buffing and polishing wheels. Figures for naturally bonded grindstones are not included. The figures for the years before 1931 may contain data on quarrying or mining certain crude materials.

Table 1 reveals that the volume of imports for consumption increased appreciably in 1937 compared with 1929, the previous year of peak industrial activity, for the following: Industrial diamonds (almost 4,000 percent); crude aluminous abrasive material (54 percent); artificial abrasives - ground, pulverized, or refined - (89 percent); and wheels, files, and other manufactures of artificial abrasives (2,780 percent). The increase in the last item is of relatively slight importance, inasmuch as the volume of imports was much less than that exported. Marked declines were shown for the following during this period: Corundum ore (45 percent); emery ore (16 percent); tripoli, diatomaceous earth and rottenstone (73 percent); hones, whetstones, oilstones, and similar products (78 percent); grindstones (49 percent); corundum and emery, ground or refined (61 percent); and wheels, files, and other manufactures of emery and corundum (58 percent).

Significant changes (see table 2) in the volume of domestic production of abrasive materials in 1937 as compared with 1929 were as follows: Increases for tripoli and rottenstone (161 percent); crude aluminum oxide in American and Canadian plants (19 percent); metallic abrasives (18 percent); and pumice and pumicite (17 percent). Silicon carbide showed a negligible increase. Decreases were shown for emery ore (65 percent); grindstones and pulpstones (48 percent); and garnet (18 percent).

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TABLE 1. - Imports for consumption of abrasive materials[1]

		1919		1929		1937	
	Unit [2]	Quantity	Value	Quantity	Value	Quantity	Value
I - Natural abrasives							
Industrial diamonds (glaziers' and engravers' unset and miners')	carat	-	2,351,469 [3]	46,949	4,067,674	1,885,970	6,542,365
Corundum ore	ton	3,099	286,440	3,378	200,739	1,862	134,574
Emery ore	do.	8,302	235,321	5,717	100,844	4,783	87,557
Pumice, crude, $15 per ton or under	do.	(5,234)	(73,620)	8,310	84,718	8,503	51,432
Pumice, crude, over $15 per ton	do.			323	11,056	269	6,221
Pumice, wholly or partly manufactured	lb.	4,442,927	44,692	9,075,102	46,838	9,331,821	33,530
Pumice, manufactures, n.s.p.f. [4]	-	-	1,469	-	1,332	-	1,325
Flint, flints, and flint stones	ton	17,677	250,096	12,587	127,457	11,989	117,828
Diamond bort, manufactured	carat	-	-	4,567	73,200	4,203	73,069
Diamond dust	-	-	53,354	-	16,163	-	145,063
Burrstone, unmanufactured	ton	81	8,996	87	6,564	-	-
Tripoli, diatomite, and rottenstone	do.	433	12,545	2,911	23,183	778	12,207
Hones, whetstones, oilstones, and scythestones	lb.	-	12,199	610,238	48,207	137,496	43,470
II - Artificial or manufactured abrasives							
Silicon carbide	do.	54,564,443 [5]	1,241,059 [5]	48,964,313	1,549,482	45,742,599	1,442,590
Aluminous abrasives	do.	-	-	102,577,654	2,266,907	157,103,835	3,868,293
Boron carbide	do.	-	-		-	5,524	7,973
Grindstones		1,628	50,551	1,680	119,264	860	32,445
Corundum and emery grains - ground or refined.		547,349	32,128	871,549	49,321	329,121	29,445
Paper and cloth coated with natural or artificial abrasives.	ream	-	-	10,273	43,440	3,276	31,937
Wheels, files, and other manufactures or emery or corundum	lb.	-	41,039	292,982	99,830	123,106 [6]	72,925 [6]
Burrstones, manufactured.	ton	143	17,360	-	-	26	2,896
III - Manufactures of artificial abrasives							
Artificial abrasives, ground, pulverized, refined, or manufactured.	lb.	-	-	380,363	33,053	718,481	59,579
Wheels, files, and other manufactures	do.	-	-	2,822	4,913	81,356	5,882
Grit, shot, and sand of iron and steel	do.	1,020,804	17,718	1,467,583	26,239	1,341,518	28,871

1/ From Foreign Commerce and Navigation, U. S. Department of Commerce. 2/ Tons are long tons, 2,240 lb. 3/ Includes manufactured bort. 4/ "N.s.p.f." indicates "not specifically provided for." 5/ Includes all crude artificial abrasives. 6/ Includes garnet.

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TABLE 2. - Domestic production of abrasive materials sold or used by producers 1/

		1919		1929		1937	
Natural abrasives	Unit	Quantity	Value	Quantity	Value	Quantity	Value
Emery ore	ton	2,601	23,203	924	10,722	320	2,780
Pumice and pumicite	do.	36,051	116,835	60,873	318,579	71,007	301,956
Grinding pebbles and liners	do.	9,448	85,302	4,630	66,178	2/	2/
Tripoli and rottenstone	do.	66,934	713,501	38,011	545,658	99,363	450,570
Hones, whetstones, oilstones, etc.	do.	1,463	235,943	838	212,017	810	112,841
Garnet	do.	4,944	310,131	5,961	435,420	4,863	382,535
Artificial abrasives							
Silicon carbide	do.	55,180 3/	7,465,849 3/	30,309 4/	3,060,401 4/	30,365 4/	2,215,318 4/
Aluminum oxide	do.			72,614 4/	6,471,373 4/	86,401 4/	4,749,497 4/
Millstones, burrstones, etc.	-	-	66,972	-	31,407	-	8,305
Grindstones and pulpstones	ton	46,865	1,336,015	27,736	1,241,546	4,541	572,708
Metallic abrasives	do.			23,789	1,289,922	28,031	1,399,772

1/ From Mineral Resources and Minerals Yearbooks, Geological Survey and Bureau of Mines, U. S. Department of the Interior.
2/ Bureau of Mines not at liberty to publish figures.
3/ Includes all American production of artificial abrasives and Canadian production of silicon carbide and aluminum oxide.
4/ Includes American and Canadian production.

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In the field of abrasives manufactures (see table 3) the most significant change shown over the period 1830 to 1929 is the decline in importance of the units of the abrasives industry engaged in manufacturing grindstones, millstones, whetstones, oilstones, and similar products. In 1880 the establishments producing this group of products represented 76 percent of the total number of plants in the abrasives industry (excluding plants producing metallic abrasives), paid 70 percent of total wages, and their products represented 56 percent of the total value of the industry's output. In 1929 the plants producing this formerly important group of abrasives comprised only 7 percent of the number of manufacturing establishments, paid only 2.3 percent of total wages, and produced only 1.7 percent of the total value of abrasives manufactures. This structural change in the industry is indicative of the extent to which mechanization or mechanical application of abrasive materials has replaced their use manually and in the form of relatively slowly operated mechanical units.

Abrasives are used in several forms of which the most important are wheels, drill bits, coated papers and tapes, grain, powder, and sticks. They may be divided into two types, natural and artificial. The former comprises minerals that receive little or no treatment other than crushing, grinding, and grading; the latter, those manufactured by physical and chemical changes, usually at high temperature.

ARTIFICIAL ABRASIVES

Speeding-up of unit operations in the metal-forming industries has hastened the replacement of softer and slower-cutting natural abrasive materials by those made of the harder, tougher, better-controlled artificial types. Although still preferred for certain operations, both natural corundum and emery have gradually been replaced by fused alumina. However, emery, although largely outmoded as the principal constituent of grinding wheels, is still widely used in the manufacture of abrasive papers and tapes.

Imports of artificial abrasives have been large, greatly exceeding domestic production, but have come chiefly from Canada, a friendly country. Moreover, these plants are just across the border, mostly near Niagara Falls, and are owned or controlled by American concerns that have their main offices, as well as their principal crushing, grinding, and finishing plants, in the United States. Crude artificial abrasive materials are admitted duty free, but crushed, ground, or refined abrasives are subject to an import duty of 1 cent a pound. As the manufacture of crude abrasive material is relatively simple, being conducted in arc- or resistance-type furnaces, which are partly dismantled after each charge, production of the crude materials now carried on largely in Canada could be transplanted to any of the hydroelectric power developments in the United States without probhibitive capital outlay or time lag. Raw materials and supplies for producing artificial abrasives are available in ample quantities in this country. Even bauxite used in making fused alumina is mainly produced domestically, although that used in making aluminum is largely imported. Certain manufacturers of fused alumina own bauxite deposits and are thus assured of an adequate supply of this essential raw material.

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TABLE 3. - Abrasives manufactured in the United States 1/

Year	Industry group	No. of establishments	Wage earners, average for year	Wages, thousands	Costs, materials, fuel, electrical energy, thousands 2/	Value of product, thousands
1939	Abrasives, wheels, stones, paper, cloth, etc.	124 3/	7,734 3/	10,683 3/	$26,506 3/	$71,271 3/
1937	do.	103	9,760	14,250	29,339	77,954
1935	do.	94	6,776	8,351	20,734	53,867
1933	do.	77	4,890	4,981	11,349	30,159
1931	do.	73	4,614	5,540	11,727	31,647
1929	Emery wheels, other abrasive and polishing appliances	67	3,873	5,820	12,417	32,154
	Grindstones, pulpstones, millstones, hones, whetstones, and similar products.	6	174	182	341	869
	Sand paper, emery paper, and other abrasive paper and cloth	11	1,228	1,740	8,375	17,219
1925	Emery wheels, other abrasive and polishing appliances	63	3,352	4,770	11,104	25,730
	Grindstones, pulpstones, and millstones	21	454	560	292	1,361
	Hones, whetstones, and similar products	6	156	158	394	787
	Sandpaper, emery paper, and other abrasive paper and cloth	12	1,230	1,714	7,342	15,623
1921	Emery and other abrasive and polishing appliances	53	2,894	2,876	6,184	12,559
	Grindstones, pulpstones, and millstones	17	503	515	458	1,499
	Hones, whetstones, and similar products	7	95	93	97	300
	Sandpaper, emery paper, and other abrasive paper and cloth	12	680	868	3,592	6,462
1909	Emery and other abrasive wheels	51	1,943	1,156	2,651	6,711
	Grindstones	14	1,394	638	468	1,688
	Hones and whetstones	18	173	72	110	268
	Sandpaper, emery paper, and cloth	10	611	370	2,382	4,352
1900	Emery wheels	34	546	303	509	1,382
	Grindstones	25	1,167	407	264	1,089
	Hones and whetstones	18	189	73	64	196
	Millstones	3	37	21	31	76
	Sandpaper, emery paper, and cloth	9	274	144	681	1,176
1890	Emery wheels	17	245	135	187	726
	Grindstones	9	124	52	35	122
	Hones and whetstones	9	57	19	6	54
	Millstones	4	24	13	18	47
	Sandpaper, emery paper, and cloth	9	206	104	782	1,250
1880	Emery wheels	11	112	58	110	333
	Grindstones	14	231	57	85	185
	Hones and whetstones	25	225	53	92	224
	Millstones	16	174	97	173	356
	Sandpaper, emery paper, and cloth	6	82	31	148	262

1/ From Census of Manufactures, U. S. Department of Commerce. 2/ In 1921 and earlier years, figures represent cost of materials only.

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A survey of the artificial abrasives industry, excluding metallic abrasives, made some months ago by the Grinding Wheel Association, revealed that the present plant capacity for the industry - including crude material, grains, and finished wheels - exceeded the volume of products in 1937 by more than 50 percent. This survey revealed further that the maximum production possible without construction of any additional facilities amounted to 182 percent of production in 1937. In the manufacture of paper and cloth abrasives the figures were even higher.

Silicon carbide

Of all the abrasives extensively used in industry, silicon carbide ranks next to the diamond in hardness. Compared with fused alumina, silicon carbide is harder but less tough. Owing to the relative brittleness of its grains, it is usually recommended for grinding materials of low tensile strength, such as cast iron, brass, bronze, aluminum, leather, pearl, marble, and stone. For grinding materials of high tensile strength (more than 50,000 pounds a square inch), including plain carbon and alloy steel, alumina abrasive wheels are used.

The first known commercial production of a few pounds in 1891 sold for $40 a carat and was used for lapping jewelry, an operation previously requiring diamond dust. The production of crude silicon carbide in the Western Hemisphere is carried on in American owned or controlled plants in Canada, although there is some production on this side of the border at Niagara Falls. Crushing, grinding, grading, and fabricating operations are mainly performed in the United States. The essential raw materials of manufacture are silica sand and coke, which are mixed with small amounts of common salt and sawdust. The mixture is heated in an electric furnace, and both crystalline and amorphous silicon carbide produced. Only the former product, however, can be used as an abrasive. All requisite materials for the manufactures of silicon carbide are abundantly available in this country. Imports from countries other than Canada have been negligible in recent years and much less in volume than exports.

Fused Alumina

Since it first appeared as a commercial product in 1901, fused alumina has displaced natural abrasive materials in many operations. It is not quite as hard as silicon carbide but is more than twice as important as regards tonnage used for abrasive purposes. The principal center of production in the Western Hemisphere is at Niagara Falls, where it is produced on both sides of the border. There is also a plant at Anniston, Ala.

Unlike silicon carbide, aluminum oxide is made in the high heat of an arc-type furnace. The charge contains calcined bauxite, coke, and iron borings. Natural corundum is used in one patented process to make a pure white product, but the same result has been obtained by re-treatment of the material produced from calcined bauxite.

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France, Germany, and Norway have exported aluminous abrasives to this country in the past, but the quantities received were relatively insignificant and ceased in 1937.

Boron Carbide

Although boron carbide is the hardest artificial material known to man, it has not been used extensively as an industrial abrasive. At present it is employed mainly in two forms, (1) powder, for certain lapping operations, some of which previously required diamond dust; and (2) in molded parts, for sand-blast nozzles and where a wear-resisting material is required. As far as is known, the material has not been used in grinding wheels on a commercial basis.

In common with aforementioned artificial abrasives, boron carbide is made in an electric furnace. The boron is derived from boric acid, of which the United States has an exportable surplus, and the carbon from coke. The crude material is produced in a Canadian plant by a single manufacturer, whose process is covered by patents. In 1937 imports for consumption totaled 5,524 pounds valued at $7,973.

Metallic Abrasives

The principal metallic abrasives output of which has increased almost constantly since 1917 are iron or steel shot, grit or sand, and steel wool or shavings. Iron shot is made by passing molten pig iron or cast-iron scrap in front of a steam jet that breaks up the metal into spherical drops, which, in turn, solidify and are chilled in a tank of water. The metal balls are then reheated and allowed to cool gradually, thus losing their brittleness. After being graded according to size, the smaller balls are used in blasting equipment to clean metal castings, forgings, and metal parts. Those over 15-mesh are used in sawing, grinding, and polishing marble and granite, and balls too large for this purpose are crushed to form steel grit. Grit is also made by crushing and grinding quickly cooled, high-carbon steel, with subsequent hardening. Fine sizes are used to saw stone and marble, in the manufacture of steel cement, and in foundry blasting equipment.

Before 1914 the various grades of steel wool or shavings used to remove paint and finish wood and metal surfaces in competition with abrasive papers were mainly imported from Germany and Switzerland. As a consequence of the World War of 1914-18 and the increased tariff duties on imports since 1922, the domestic industry expanded so that the United States now exports substantial quantities.

The domestic output of metallic abrasives increased from 2,360 short tons valued at $274,200 in 1919 to 42,015 short tons valued at $1,743,859 in 1939. The 1939 valuation amounted to more than 26 percent of the total value of all artificial abrasives.

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NATURAL ABRASIVES

In the production of certain natural abrasives the United States does not occupy the position of self-sufficiency exhibited with regard to the artificial or manufactured varieties.

Not only industrial diamonds but also corundum ore, certain kinds of pumice, tube-mill linings and pebbles, and special razor hones have been largely imported, so that actual or prospective curtailment of imports may impose certain hardships and readjustments. Only three of the abrasive materials regularly imported have come from the Axis Powers or countries that have fallen into their hands, and it is fortunate that domestic materials may be substituted for these items. Industrial diamonds are the only abrasives that might eventually be listed as a strategic material as defined by the Army and Navy Munitions Board or the National Defense Council and scheduled for inclusion in the stock-piling program.

Industrial Diamonds

Essential to peacetime needs and even more vital to national defense is an adequate supply of industrial diamonds. This extremely hard form of carbon, too imperfect in form or color for gem purposes, is used not only directly as a cutting agent but also to keep in condition cutting and grinding tools made from other very hard materials. When dressed in tool ends for boring or drilling purposes or for truing grinding wheels, diamonds are the most efficient material available. In dies for wire drawing, diamonds retain their shape and size longer than any possible substitute. Desire for increased speed in shaping hard steel alloys for the automobile industries, as well as very hard carbide cutting tools, has led to the use of diamond chips and dust as the abrasive ingredient of resin and metal-bonded grinding wheels. One source of the diamond chips and dust so used is the waste material produced in cutting gem diamonds.

Except for meager occurrences in Arkansas and sporadic finds in the glacial drifts of Wisconsin and other States, diamonds have not been produced in this country; and the United States, with the other industrial nations of the world, must look mainly to Africa for its supplies. In the Western Hemisphere diamonds have been produced commercially only in Brazil, British Guiana, and Venezuela. During 1939 production from the last two countries totaled only 51,500 carats, less than 0.5 percent of world production. In recent years Brazil has supplied less than 15 percent of our industrial diamond requirements.

Several attempts have been made to produce diamonds artificially by subjecting pure carbon to tremendous pressure, but the so-called "synthesis" has not produced stones large enough for industrial or gem purposes.

An indication of the importance of diamonds in our industrial life and the increased demands for this abrasive is the rise in imports of industrial diamonds, 46,949 carats in 1929, 1,885,970 carats in 1937, and

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and 3,578,730 carats in 1939. The excessive imports for 1939 increased substantially the stocks held by American dealers and resulted from the flight of diamonds to a place of safe keeping. Imports of over a million carats each in April and May 1939 were, of course, abnormal and merely anticipated the initiation of hostilities a few months later.

The demand pattern for industrial diamonds has undergone a vast change since the last war. At that time the industrial diamonds used were larger than 1 carat, and there was relatively small demand for small stones unsuitable for gem purposes. The old diamond-drilling practice of using a few large stones in a drill bit has been superseded by using up to 150 or more stones as small as 25 to the carat. This extensive use of smaller stones, both in drill bits, which now can be mechanically set, and in diamond-set tools largely used in the automobile and airplane industries, has led to considerable reduction in the average value per carat of the industrial diamonds consumed by American industry. The average value a carat of industrial diamonds imported for consumption decreased from $86.64 in 1929, to $3.47 in 1937, and to $2.73 in 1939.

In September 1939, at the outbreak of war, the estimated stocks in this country totaled about 1,500,000 carats, adequate to meet normal requirements for 6 to 9 months. Stocks late in 1940 probably were less than they were a year earlier, owing to increased consumption and a decrease in imports, which amounted to only 1,475,230 carats in the first 9 months of 1940. As long as there is no change in the national status of the Central and South African countries concerned, and while sea and air traffic continue, we may assume that requirements can be supplied by imports, as more than 95 percent of world output is marketed by the Diamond Trading Co., a British syndicate. The hard carbides of boron and silicon are possible substitutes, but for many operations only at a great sacrifice in efficiency.

Imports of diamond bort, drilled for wire-drawing dies, decreased from a normal average of 3,500 to 4,500 carats a year to 1,100 and 1,400 carats in 1938 and 1939, respectively. Since the fall of France, formerly the center of this industry, imports have decreased further. Dies have been drilled successfully in this country to one-thousandth inch in diameter, but for the drilling of holes to four ten-thousandths inch the necessary tools and skill required had not been developed in the United States.

Corundum

Of the minerals found in nature, corundum - natural aluminum oxide - is next to the diamond in hardness. Almost invariably it contains impurities, such as iron oxide and water of crystallization, that tend to reduce its hardness. Material from different deposits or different parts of the same deposit may vary in chemical composition, so that the abrasive quality of corundum is not constant. In fact, the difficulty of obtaining natural corundum of uniform grade led to its replacement by artificial corundum, whose physical properties are susceptible of close control. The principal exporting country has recently begun to supervise grading, with a result that a more uniform grade of corundum is available.

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Before fused alumina was developed as an abrasive about 1902, corundum was widely used as the abrasive ingredient of wheels and in some coated papers and tapes; it is now preferred to artificial corundum in only a few operations, such as in snagging wheels for grinding malleable iron and for precision-grinding glass. Smaller but increasing quantities are used instead of bauxite in the manufacture of white aluminous abrasives.

Although deposits of corundum occur in North Carolina, Georgia, Montana, and South Carolina, domestic mines have operated since 1905, only during the war years 1917 and 1918, when 820 and 365 tons, respectively, were produced. Canada formerly contributed a considerable tonnage, but its mines have been idle since 1921. In recent years almost the entire world output has originated in the Union of South Africa. Russia has reported a substantial production, but this reported output is believed to include a large quantity of emery, which is mined in the same locality.

The United States is the largest consumer of corundum, normally taking more than 60 percent of the South African production; the remainder has been exported, principally to Great Britain and Germany. Exploitation of the South African reef deposits, where labor is cheap and the material easily concentrated, has reduced production costs far below those in the United States and Canada; this, in turn, has revived the use of corundum which threatened to be replaced completely by fused alumina.

In spite of the complete dependence of this country on imports, the Army and Navy Munitions Board has not declared natural corundum of strategic or even critical importance, apparently because artificial corundum is generally an acceptable substitute. Snagging wheels of fused alumina are reported to be satisfactory, and a large optical concern is known to have stocked a considerable quantity of natural corundum. If imports from South Africa should be cut off completely, reopening of domestic mines, as in the last war, would provide adequate quantities, although at a much higher price.

Emery

Large quantities of this abrasive, which is an intimate mixture of aluminum oxide and iron oxide (magnetite with or without some hematite), have been imported from Greece and Turkey. Emery mined in Massachusetts, New York, and Virginia differs in chemical composition, containing less hard alumina, more iron oxide, and, in addition, magnesium oxide. This magnesium oxide and larger iron content of domestic emery makes it softer and consequently less satisfactory for most abrasive purposes than the imported emery. Currently, domestic emery is used mainly in polishing pastes and compounds.

Formerly, Greek or Naxos emery was used in grinding wheels, but manufacture of wheels made of emery from this source has virtually been discontinued, as the emery has been replaced by fused alumina. Turkish emery is chiefly used on abrasive papers and tapes and for finishing extremely hard wood and metals. Both these imported emeries are used in grain form for glass grinding and beveling, as the abrasive constituents of pastes and polishing compounds, and on papers and tapes for finishing metals and hardwoods.

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With decreasing use of emery grinding wheels and wider application of artificial abrasives, both imports and domestic production have declined sharply, the former from an average of more than 15,000 tons a year in the 5-year period 1910-14 to less than 5,000 tons in 1937, and the latter from about 800 tons a year during the same 5-year period to about 300 tons in 1937. Extension of European blockade efforts to exports from Greece and Turkey would not be a serious blow to industries consuming imported emery, because the net result would be merely to accelerate the declining trend in consumption. Domestic production and further substitution of garnet and fused alumina can replace imported emery for all essential purposes under emergency conditions. According to reports, a large manufacturer of munitions will substitute a coated artificial abrasive for emery in finishing guns on a defense contract.

Garnet

The United States not only is self-sufficient in the production of abrasive garnet but also produces most of the world output. Garnet deposits have been mined in Spain, Madagascar, India, Canada, and other countries, but, except for Spanish production before 1925, they have contributed but little to world supplies. Small quantities of garnet have been imported from Spain, but in 1925 that country virtually discontinued production. Spanish garnet, which is softer than that produced in this country and sells at a much lower price, is again being quoted in trade journals after a lapse of several years.

The peak of domestic production - 9,000 tons - was reached in 1923; it came from New York, New Hampshire, and North Carolina. Garnet is used principally on abrasive papers and tapes, in which form large quantities are consumed in finishing hardwood and leather, especially in the shoe industry. Some of the softer metals are also finished with garnet abrasives. Loose-grain garnet is used in glass grinding and for sand blasting. Fine grits on open coated paper have replaced pumice to some extent in rubbing down painted surfaces, and large quantities are consumed by the automobile industry. Domestic reserves and plant capacity are adequate to meet any increased needs for national defense.

Pumice and Pumicite

These natural siliceous abrasive materials, which occur extensively throughout the Western States and in Kansas, Nebraska, and Oklahoma, are widely used. The finest air-floated powders supply the abrasive ingredient for certain toothpastes; slightly coarser particles are used for finishing gold, silver, and aluminum articles. Coarser grades are employed for glass cutting and beveling, piano finishing, and polishing operations in tumbling barrels. The largest single application of pumicite is in scouring powders and soaps, for which purpose deposits in Kansas, Nebraska, and Oklahoma are extensively worked.

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Lump pumice is utilized to finish stone, marble, and leather, to clean buffing wheels, and in lithographic work. In addition, increasingly large amounts of pumice and pumicite are being used for thermal insulation and as light-weight aggregate material.

Before Italy entered the war in 1940, most of our imports of pumice came from Lipari, an island a few miles off the coast of Italy, where American firms carried on some of the mining operations. Certain users of abrasive pumice, notably furniture manufacturers, have long preferred imported pumice to that from California and Oregon. Domestic producers, moreover, have been at a disadvantage in competing for the eastern markets because of high freight rates. Even during the World War of 1914-18 many former consumers of Italian pumice began to substitute domestic pumice for that formerly imported. With the better technology developed during recent years in preparing domestic pumice, there appears to be no reason for shortages in the best grades. A large western producer, who immediately expanded output when Italy entered the war, reports that his commodity has proved acceptable to furniture makers and certain other users who previously specified imported pumice.

Flint, Flints, and Flint Stone

Flint pebbles and liners were at one time the most important grinding mediums in cylindrical or conical grinding mills, but in recent years they have been replaced to a large extent by steel balls and liners. However, in the grinding of feldspar, paint materials, enamel, and clays, where steel abraded from the grinding medium would contaminate the finished product, flint is still the essential abrasive material. Before the blockade was extended to virtually the entire continent of Europe early in 1940 this country depended largely on Belgium, Denmark, and France for imports of flint pebbles and liners. In 1937, when only one domestic company was in operation (producing liners and artificial quartzite pebbles), imports of pebbles, liners, and potters flint (more than 95 percent of which came from these three countries totaled 11,989 tons valued at $117,828. Official import statistics do not separate the several items under the customs classification "Flint, flints, and flint stones, unground," but it is known that the tonnage of potters' flint is relatively small. Domestic substitutes, consisting of quartz, novaculite, and quartzite, may require slight changes in grinding, but sufficient quantities are available in domestic deposits. Twenty-three concerns in 11 states have recently indicated that they can supply quartz pebbles or liner blocks. Other companies have found that contamination by iron from steel balls and steel liners was less than they expected and have therefore ceased using flint altogether.

Hones

As yet no domestic deposits have been discovered that yield fine-grained razor honestone comparable to that previously imported from Belgium and known as "coticule." This natural abrasive stone is also used to sharpen microtome knives used in the preparation of microscope slide specimens. Artificial stones of similar grain size (the natural stone has about a billion

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crystals to the cubic inch) are said to be more expensive than imported stones. Although the geological conditions necessary to produce the coticule have been duplicated in certain parts of the United States, no discovery of similar stone has been recorded; and, with imports from Belgium nonexistent, the more expensive artificial item must necessarily suffice.

The novaculite deposits of Arkansas, sandstones of Indiana and Ohio, and mica schists of New Hampshire can supply ample quantities of raw stone for the manufacture of other hones, oilstones, whetstones, and scythestones used for sharpening hand tools and agricultural implements. In addition, artificial abrasives are used to a large extent and could be substituted further for the declining imports of these abrasive materials.

Grindstones

Necessary to the production of natural abrasive grindstones are fairly thick beds of a compact, uniform sandstone with joint planes spaced far enough apart to permit quarrying blocks that will yield stones at least 5 feet in diameter. Finished stones are used to sharpen saws, files, machine knives, scythes, and shears and in the agricultural implement and die-making industries.

Production and imports of natural grindstones have declined for several years, owing in great part to their replacement by artificial stones, which are safer at high speeds and more uniform in texture. In recent years, production of domestic grindstones has been confined to Ohio and West Virginia, the former producing the bulk of the output.

Grindstone imports in 1937, which were predominantly from the United Kingdom, declined 50 percent in quantity and 72 percent in volume compared with 1929. Domestic deposits of grindstone material are more than ample to supply all possible domestic requirements.

Pulpstones

In the production of pulp for paper making, coarse-grained wheels revolving about 225 times a minute separate, by a tearing action, long, thin fibers from pulp wood, which is pressed against the stones. Stones for this purpose are produced in the United States from extensive sandstone deposits in West Virginia and Washington. Ohio sandstone also has been used. Artificial built-up stones have made inroads in recent years in supplying the abrasive needs of the paper industry, and the output of natural pulpstone in this country will probably never exceed its 1921 peak of 10,030 tons valued at $750,063. The artificial built-up stones permit wider variation in texture, which, in turn, makes possible the production of wood fibers of varying thickness. Although no separate figures are available, imports of pulpstones are known to be inconsequential.

Quartz and Quartzite

Crushed and ground quartz and quartzite are used as medium-hard abrasives in the form of sandpaper, metal buffing compounds, and scouring

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soaps and powders. Nonabrasive uses, especially metallurgical, consume the greater part of the material mined in more than a dozen States. Domestic deposits are extensive and widely distributed, and as a result the average value a ton in 1939 was $4.38. Imports are negligible.

Ground Sandstones and Sand

As abrasives, ground sandstones and sand are used mainly in cleansing and cleaning preparations. They are also employed for glass grinding and sand blasting and in the manufacture of sharpening stones and sandpaper. Domestic deposits of these raw materials are extensive, and because of their low average value a ton imports have been unable to compete with domestic production.

Diatomite

Among the milder abrasive materials is diatomite, a fine-grained material composed of the siliceous skeletons of aquuatic plants. It is used as the abrasive or gritty ingredient of a large number of metal polishes, powders, and pastes. The quantities used for abrasive purposes, however, are relatively negligible compared with the amounts consumed each year for insulation and filtration. The large marine deposits of diatomite in California and Oregon, with the other widely distributed domestic deposits, eliminate the necessity of imports.

Tripoli

Tripoli is a white, chalklike, soft silica, an alteration product of siliceous limestones or novaculite. This fine-grained porous material is used mainly in grease bricks, which, in turn, are employed for buffing and polishing metals. The finely powdered form of tripoli is utilized in scouring compounds and soaps. Although current production is centered in Missouri and Oklahoma, the material has been mined in Tennessee, Georgia, and other States. Pennsylvania rottenstone, which is grouped with tripoli in Bureau of Mines statistics, is a siliceous-argillaceous limestone of fine-grained texture used for buffing and polishing compounds.

Imports of diatomite and tripoli have been insignificant during the past 3 years compared with domestic production.

Soft Abrasives

Next to quartz on the Mohs hardness scale ranks feldspar which, when ground, is widely used in scouring pastes and compounds and also as an ingredient of the bonds for abrasive wheels. The quantity consumed for abrasive purposes was less than 1 percent of the 1939 domestic production.

Vienna lime (unhydrated burnt dolomite) has proved to be the most effective polishing agent for nickel-plated surfaces. Formerly the material was imported from a deposit near Vienna, Austria, but the Wisconsin dolomite have produced a superior material that has entirely replaced imports.

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Other soft abrasives, such as chalk and china clay, sometimes are used as milk abrasive agents in powders and pastes for metal polishing. All are abundantly available in this country.

Metallic Oxides

In the finished surface dressing of metals and other materials the metallic oxides are widely employed in pastes, polishes, and powders. Crocus, a hydrated iron oxide, produces a high polish on steel, tin, and copper surfaces, but is being replaced to some extent by the oxide of chromium. English crocus manufactured by a different process than that used in this country is considered superior to the domestic product because it is said to give a brighter finish.

Rouge compound, also an oxide of iron, is used universally in buffing and polishing gold, silver, and platinum; in powdered form, large quantities are employed in polishing plate glass. Black rouge is a black magnetic oxide of iron and is used in buffing aluminum and steel. Green rouge (chromium oxide) is the standard buffing agent for stainless steel and chromium-plated surfaces. When the oxides of tin and lead are mixed and heated at high temperatures, putty powder is formed; this material is utilized to polish granite and marble.

Of the metallic oxides used for buffing and polishing, only those of chromium and tin are derived from strategic minerals; but the quantities consumed for abrasive purposes are relatively insignificant compared with consumption for other purposes.

COATED ABRASIVES

Coated abrasives are made by gluing grains of abrasive materials to papers and cloths. In such form the abrasive can be used in the slow hand-rubbing employed in finishing some high-grade furniture and on the endless belts, disks, or drums of high-speed sanding and buffing machines. The manufacturing process consists essentially in sprinkling the graded abrasive grains evenly on a moving belt or cloth that has been coated with strong glue. Plant capacity is ample and can readily be expanded to satisfy larger defense requirements as they develop.

The basic materials for manufacturing coated abrasives are graded abrasive grains, high-quality glue, heavy manila-fiber paper, and cotton drill, all of which, except emery grains, corundum, and manila fiber, are available in North America in ample quantities. Manila fiber, a strategic material on the Army and Navy Munitions Board list is imported from the Philippine Islands. A combination of cotton drill and heavy kraft paper has proved to be an excellent backing and superior to either cloth or paper backing for many purposes.

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GRINDING WHEELS

Grinding wheels are among the most important tools of modern industry. Without these effective grinding aids, production of modern automobile and airplane engines would be impossible. Introduction of these wheels, made of artificial abrasive material, has produced vast changes in machine-shop practice, resulting in faster fabrication and improved precision in turning out machine parts. Several operations previously possible only with lathes and other machine tools are now performed by abrasive wheels turning at several hundred revolutions a minute. The bonding agents of natural sandstone wheels do not safely permit high-speed operation, whereas vitrified, silicate, shellac, rubber, and resinoid bonded wheels operate safely at surface speeds up to 9,000 feet a minute and to 16,000 feet for certain thin cut-off wheels - 6,000 feet a minute being the general average operating speed.

American genius has pioneered in the development of grinding wheels. Ceramic-bonded and shellac wheels are known to have been developed in the United States, and rubber-bonded wheels probably were also developed in this country. Annual production of grinding wheels in the United States is valued at more than $20,000,000.

The manufacturing process, in general, consists of mixing the abrasive grains and bonding material, forming the mixture in molds (by hand or hydraulic pressure), shaving or trimming to predetermined sizes, firing, finishing, and grading. With ample supplies of abrasive materials and bonding agents - the latter are also abundantly available in this country - the only conceivable bottleneck in grinding-wheel manufacture would be the capacity of currently existing kilns or firing plants. In the vitrified manufacturing process, firing requires 3 to 15 days, depending on the size of the wheel. The other processes - silicate, shellac, rubber, and synthetic resin - require up to four days. The recent survey of plant capacity made by the producers of abrasive grain and grinding wheels indicates that no bottlenecks are liable to develop in the grinding-wheel-manufacturing industry.

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